TIME-TEMPERATURE-STRESS CAPABILITIES OF COMPOSITE MATERIALS FOR ADVANCED SUPERSONIC TECHNOLOGY APPLICATIONS

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1.0 INTRODUCTION

This progress report covers work performed during the forty-ninth monthly reporting period, 1 July to 1 August 1977, under Contract NAS1-12308. This work is under the technical direction of Mr. Bland Stein.

2.0 SUMMARY

Two doubler bond failures have occurred in the unidirectional B/Al flight simulation specimens. New doublers will be attached, and the specimens will be returned to test. The residual strength testing of the Phase I B/E and G/E flight simulation specimens and the specimen configurations are discussed. Quality assurance testing of the full size G/PI Phase II panel was completed and results are presented. In the screening test portion of the new material evaluation full size panels of HT-S/PMR-15 and HT-S/710 have been fabricated and submitted for quality assurance testing.

3.0 PHASE I

3.1 Long Term Flight Simulation Testing. The apparatus performed well during the month of July. Table I lists the average number of exposure hours per week for the seven sets of specimens and the maximum number of exposure hours for any one set during that week. Table II shows the total exposure hours for the seven sets of composite specimens as of July 25, 1977.

One problem has occurred with the unidirectional B/Al material. Two of the specimens exhibited failures in the adhesive bonds between the B/Al and the titanium doublers. The adhesive, HT-424, which is quite porous slowly oxidized and eventually failed under the much larger loads used for the unidirectional B/Al. New doublers will be attached and the specimens will be reinstalled in the exposure apparatus.

3.2 Residual Strength Testing of Flight Simulation Specimens. Cutting of the 10,000 hour B/E and G/E flight simulation specimens for residual strength testing has been completed. The 1/2 inch wide unnotched tensile and fatigue specimens were cut from the portions of the flight simulation specimens between the stiffening grids. This was done because earlier tests on material from the unfailed end of a G/E specimen that failed in 4053 hours showed considerable variation in tensile properties across the width of the specimen. Specimens that were shielded by the stiffening grids gave tensile values of 79.9 ksi and 79.0 ksi while a specimen that was cut from between the grids gave 23.5 ksi. The notched flight simulation specimens are 3 inches wide with three equally spaced 1/4 inch diameter holes across the width. Shearing of the specimens would produce three identical 1 inch wide residual strength specimens with a centrally located hole. For composite materials, however, the specimens must be cut with a saw having a finite blade width (approximately 0.06 inch). Consequently, the notched tensile and fatigue specimens can be cut from the flight simulation specimen in at least three different ways. (Equal widths with offset holes; unequal widths with centered holes; equal widths with centered holes.) A check of Paterson's book, Stress Concentration Design Factors, shows that the

various configurations have very little difference in K_t factors. The one selected was specimens of equal widths with offset holes in the two outer specimens. The difference in $\frac{\sigma \text{ max.}}{\sigma}$ values for the specimen with a centered hole and the one with an offset hole is negligible (3.28 versus 3.30). A Celanese type of specimen will be used for the compression tests. The G/E specimens will be made by laminating four 3/4 inch wide pieces together. From this piece, two 1/4 inch wide compression specimens will be cut. This type of specimen will use the entire width of one end of the flight simulation specimen. Since there were no failures of the B/E flight simulation specimens and sufficient material is available, two types of B/E Celanese compression specimens will be tested. The first is identical to that for G/E. The second will be made by laminating four pieces together which are cut from the areas between the grids. Two flight simulation specimens will provide enough material for three 1/4 inch wide compression specimens.

Bonding of doublers will be required on only one end of each of the residual tensile and fatigue specimens as the titanium doubler from the flight simulation specimen is still attached to the other end. Bonding of these doublers and laminating of the compression specimens is currently in progress.

4.0 PHASE II

4.1 Phase II Specimen Fabrication. The Phase II $[0^\circ \pm 45^\circ]_S$ HT-S/710 graphite/polyimide panel for the 25,000 hour flight simulation specimens has been cut into specimens and quality assurance tensile tests performed at 75°F and 450°F. The results are listed in Table III. The tensile properties are considered to be acceptable, and fabrication of the flight simulation specimens will be initiated.

5.0 NEW MATERIAL EVALUATION

5.1 Screening Phase. The status of the three graphite/polyimide systems under test in the screening phase of the new materials evaluation is described below.

1. HT-S/NR-150B2 - Flexural specimens have been cut and are ready for the moisture exposure and thermal aging tests. These tests will begin as soon as specimens of the other two systems are available.

2. HT-S/PMR-15 - A full size (18 inch x 24 inch x 12 ply) panel has been fabricated and ultrasonic C-scanned. The C-scan gave an indication of some differences from one side of the panel to the other. In an attempt to determine what these differences were, several tests were performed on material from, according to the C-scan, good and bad areas. Small differences were found in (a) specific gravity: 1.50 versus 1.46, (b) percent fiber volume: 62.8 versus 61.0, (c) percent voids: 1.2 versus 3.4, (d) flexural strength: 102 ksi versus 94 ksi and (e) thickness: slight gradient from one side to the other with the so-called bad area being thicker. The conclusion drawn from these tests is that the C-scan is not, at this time, a good QA test. Because one side of the panel was slightly better than the other all test specimens will

be cut from that side. The remainder of the QA tests are in progress and will be reported next month.

3. HT-S/710 - A full size (18 inch x 24 inch x 12 ply) panel has been fabricated and ultrasonic C-scanned. No significant variations were noted in the C-scan. Test specimens for the quality assurance evaluation have been prepared, and testing is in progress. Results will be reported next month.

6.0 WORK TO BE DONE NEXT MONTH

Specimens from the 10,000 hour B/E and G/E flight simulation specimens will be prepared and residual strength tensile and fatigue testing will begin. The Phase II 25,000 hours flight simulation specimens of HT-S/710 graphite polyimide will be fabricated.

Quality assurance testing of the HT-S/PMR-15 and HT-S/710 full size screening test panels will be completed. Specimens will be cut from the panels, and work will begin on the moisture exposure and thermal aging tests. Long term flight simulation, ambient aging, and thermal aging tests currently in progress will continue.

Table I. Weekly Exposure Hours for Long Term Flight Simulation

Week Ending	Average Exposure Hours	Maximum Exposure Hours
4-4-77	80	83
4-11-77	160	163
4-18-77	165	166
4-25-77	147	166
5-2-77	166	169
5-9-77	168	169
5-16-77	105	105
5-23-77	153	157
5-30-77	162	168
6-6-77	157	157
6-13-77	158	163
6-20-77	144	158
6-27-77	139	168
7-5-77	141	152
7-11-77	130	135
7-18-77	145	155
7-25-77	157	168

Table II. Total Exposure Time in Hours for Long Term Flight Simulation Specimen

	Setup Number and Material System						
DATE	1. B/Al	2. G/PI	3. G/PI	5. B/E-G/E	6. B/E-G-E	8. B/E-G/E	10. B/Al
5-31-77	7667	7440	7830	-	-	-	7769
6-27-77	8244	7988	8411	299	258	258	8349
7-25-77	8722	8592	9011	905	858	854	8959

Table III. Quality Assurance Tensile Data for Phase II $[0^{o} \pm 45^{o}]_{s}$ HT-S/710 Graphite/Polyimide Panel KN-9

Specimen No.	Temperature (°F)	Load (lb.)	Ftu (ksi)	E (10^{6}psi)
D1	75	697	55.8	8.2
D2		619	56.3	10.1
D3		723	58.8	7.4
		Avg.	57.0	8.6
D4	450	828	71.4	8.1
D5		722	53.9	*
D6		735	63.4	*
		Avg.	62.9	8.1

*Extensometer Failure